**An Official ERS Statement on Physical Activity in Chronic Obstructive Pulmonary Disease**

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**Abstract**

This European Respiratory Society (ERS) statement provides a comprehensive overview on physical activity in patients with chronic obstructive pulmonary disease (COPD).

Methods: A multidisciplinary Task Force of experts representing the ERS Scientific Group 01.02 'Rehabilitation & Chronic Care' determined the overall scope of this Statement through consensus. Focused literature reviews were conducted in key topic areas and the final content of this Statement was agreed upon by all members.

Results: The current knowledge regarding physical activity in COPD is presented, including the definition of physical activity, the consequences of physical inactivity on lung function decline and COPD incidence, physical activity assessment, prevalence of physical inactivity in COPD, clinical correlates of physical activity, effects of physical inactivity on hospitalizations and mortality, and treatment strategies to improve physical activity in patients with COPD.

Conclusions: This Task Force identified multiple major areas of research that need to be addressed further in the coming years, including, but not limited to, the disease-modifying potential of increased physical activity and to further understand how improvements in exercise capacity, dyspnea, and self-efficacy following interventions may translate into increased physical activity.

Recommendation: The Task Force recommends that this ERS Statement will be reviewed periodically (e.g.every 5-8 years).

## 1. Introduction

Chronic obstructive pulmonary disease (COPD) is a highly prevalent chronic respiratory disease affecting about 10% of the adult population above 40 years of age (1). In addition to progressive chronic airflow limitation, patients with COPD commonly have multiple extra-pulmonary effects and comorbidities, which are associated with physical inactivity (2) (3). The "Global Initiative for Chronic Obstructive Lung Disease" has recommended regular physical activity for all COPD patients (2). However, the clinical relevance of regular physical activity has not been addressed in depth. The purpose of this Official European Respiratory Society (ERS) Statement is to highlight the existing science regarding physical (in)activity in patients with COPD, including, but not limited to, its prevalence, determinants, consequences, measurement, and potential treatment.

## 2. Methods

An international group of pulmonologists, physiotherapists, movement scientists, exercise physiologists, health psychologists, social psychologists, and epidemiologists knowledgeable in the area of physical activity and/or COPD research was assembled into a Task Force by the leadership of the ERS Scientific Group 01.02 'Rehabilitation & Chronic Care'. Contributors searched the scientific literature (PubMed and Database of the Cochrane Collaboration) for original studies and systematic reviews relevant to the topic Selection of relevant studies and reviews was based on the expertise of the contributors. Draft contributions were shared among committee members, reviewed and revised iteratively. Members were vetted for potential conflicts of interest according to the policies and procedures of ERS. This document represents the consensus of these Task Force members.

## 3. Definitions

Physical activity can be defined as any bodily movement produced by skeletal muscles that results in energy expenditure (4). Physical activity is a complex behavior that can be characterized by type, intensity, duration, patterns, and symptom experience. Exercise is a subset of physical activity. Exercise is physical activity that is planned, structured, repetitive, and purposeful (4). Physical activity also includes, but is not limited to, leisure-time, domestic, and occupational activities (4;5). Activities of daily living are another subset of physical activity and this term refers to a set of basic, everyday tasks required for personal self-care and independent living (6;7).

While physical inactivity can be defined simply as 'an absence of physical activity' (8), it is commonly used to represent a level of physical activity that is below an optimal or specified threshold. This concept rests on the strong evidence that lower levels of physical activity are related to poor health and predict negative health outcomes (9). In general, a healthy individual can be considered as physically inactive if either of the following criteria is not met: (1) 30 minutes of at least moderate-intensity physical activity on five or more days every week; (2) 20 minutes of vigorous-intensity physical activity on at least three days every week; or (3) an equivalent combination, which can also be accumulated in shorter bouts usually lasting 10 minutes of moderate (3 times 10 minutes) or vigorous (2 times 10 minutes) exercise (10;11). This represents a framework on which to base recommendations for physical activity promotion. However, the recommended intensity and duration of physical activity for the elderly may be different (12). Furthermore, the extent to which these recommendations apply to persons with COPD is currently unknown.

In recent years, attention has been raised regarding the adverse health effects of a sedentary lifestyle (13). A sedentary lifestyle is characterized by behaviors that do not increase skeletal muscle energy expenditure substantially above the resting level (14).

Sedentary individuals expend less than 10% of their total daily energy expenditure in performing moderate- or high-intensity activities (15).

## 4. Consequences of physical inactivity in general population and in chronic diseases other than COPD

Physical inactivity is a fundamental characteristic of many chronic diseases, both as a cause and as a consequence. Evidence suggests that reduced physical activity predisposes to greater incidence of cardiovascular disease (16;17), obesity (18), diabetes (19;20), cancer (21), dementia (22), and physical disability (23). In addition to its effect on development of chronic disease, physical inactivity may develop or worsen as a result of many diseases, owing to the sequelae of the disease and/or the associated reduction in physiological reserve. These effects of physical inactivity to both potentiate and develop from chronic disease likely explain the fact that reduced physical activity, measured either subjectively or objectively, is associated with higher overall mortality rates in the elderly (24;25). The exact mechanisms whereby physical inactivity interacts with anatomical and physiological changes related to aging and other pathological co-factors to contribute to the evolution of disease or subsequent morbidity or mortality, however, is poorly understood within the human population.

## 5. Consequences of physical inactivity on lung function decline and COPD incidence

Several population-based epidemiological studies have assessed the longitudinal effect of regular physical activity on lung function decline or COPD incidence (26-30); their main characteristics and results are summarised in Table 1. Briefly, all studies show an inverse relationship between physical activity levels and the magnitude of lung function decline in at least one of the population subgroups or physical activity variables studied. However, the association between lower physical activity levels and faster lung function decline is not consistent across all population subgroups or physical activity variables. Potential explanations for such inconsistencies include selection bias, lack of adjustment for potential confounders, and lack of consideration of changes in physical activity level during follow-up. Only one study overcomes such limitations and, interestingly, shows beneficial effects of regular physical activity on lung function decline and COPD risk in active smokers but not in former or never smokers (29;30).

## 6. Physical activity assessment

### *6.1 Questionnaires*

The physical activity of patients with COPD can be assessed using questionnaires. These instruments are commonly used in epidemiological studies and large clinical trials because they are inexpensive and easy to use (31). A variety of questionnaires exist that capture different aspects of physical activity such as amount, type, intensity, symptom experience, and limitations in the performance of 'activities of daily living' (31). The selection of a questionnaire to measure physical activity requires that the specific questionnaire fits the study aim, is properly developed and has strong psychometric properties, e.g., validation, test-retest reliability and responsiveness to change (32). In the specific case of COPD studies, additional criteria could be considered to improve validity of the questionnaire, such as the inclusion of information on low-intensity activities (31;33), or the availability of a version for interviewer-based administration (34). Other practical issues include the availability of a culturally validated version, the time required for questionnaire administration, and the ability to compare outcome levels across studies.

Recent systematic reviews have assessed all questionnaires available to measure physical activity in the elderly or chronically ill patients (35;36). From the 104 questionnaires identified in these systematic reviews, 15 were developed for use in patients with COPD. Validity was assessed in 85% of these instruments, test-retest-reliability in 69%, responsiveness in only 19%, and none of the instruments was based on a conceptual framework (37). A current Innovative Medicines Initiative project is filling this gap by developing a valid Patient Reported Outcome tool (PROactive) capturing physical activity experience in COPD (http://www.proactivecopd.com).

A common methodological issue is recall bias, which may become a limitation if not addressed in the development and validation process. Garfield *et al* assessed 4 questionnaires against physical activity measured directly by accelerometry and found that while the Stanford Seven-Day Physical Activity Recall questionnaire could identify patients at both extremes of physical activity the other 3 had a poor relationship with directly measured activity only (38). Also in two other studies the relationship between questionnaire-derived physical activity measures and accelerometer-derived physical activity measures was either not given (39) or did not allow to reliably identify extremely inactive patients (40). .

Despite limitations of questionnaires when used on an individual level, some questionnaires might be used to measure physical activity in groups of patients with COPD. However, the choice depends on matching the question to be addressed with the psychometric properties of the instrument.

*6.2 Step counters*

Pedometers are small, lightweight, portable and nonintrusive devices which measure the number of steps performed in a given period of time. From that metric estimates of distance and energy expenditure can be made (31). Many pedometers are available, and variability exists not only in cost but also in mechanism of step detection, data storage, and sensitivity. Pedometers are most accurate at step counting, less accurate in distance estimates, and even less accurate at estimating energy expenditure (41). Pedometers may underestimate the number of steps and energy expenditure during walking at slow speed, which is typical in patients with COPD (42-44). This may limit their accuracy in patients with moderate-to-very severe disease. However, pedometers may have positive role as a motivational tool aiming to increase daily activity, especially in addition to other combined interventions (45-47).

*6.3 Activity monitors*

Accelerometers are electronic portable devices that are worn on the body to detect acceleration and thereby reflect bodily movement. They quantify activity counts, and may provide an estimate of time spent above or below a pre-specified activity level, number of steps, and energy expenditure (31). The use of accelerometers has received increasing interest since they add objective data which cannot be obtained from questionnaires or pedometers.

Accelerometers can detect movement along one axis (uni-axial accelerometers), two axes (bi-axial accelerometers), or three axes (tri-axial accelerometers). Uni-axial devices provide information similar to pedometers, but with the advantage of assessing acceleration in addition to simply detecting steps. Bi-axial and tri-axial devices allow for detection of movement in a wider range of physical activities, and are therefore more sensitive than uni-axial devices (48). Activity monitors sometimes combine accelerometers with other physiological sensors (such as heart rate, skin temperature) or are used in conjunction with positioning systems with the objective of increasing their accuracy to estimate daily physical activity and energy expenditure (49-51).

The validity of activity monitors for assessment of physical activity in patients with COPD has been the subject of many investigations in recent years (31;39;42;43;49;52-61). Two studies in COPD patients recently investigated the validity of six widely used accelerometers in comparison to the ‘gold standards’ of indirect calorimetry and doubly-labeled-water (62;63). Among the six devices, the DynaPort MiniMod , the Actigraph GT3X and the SenseWear Armband (all employing triaxial accelerometers) were valid and responsive for use in COPD

(62;63). These devices were demonstrated to be valid in other studies in COPD as well (42;43;49;52;54-56;58).

Several factors may influence the outcome of physical activity monitoring. Vibration from vehicle travel can falsely elevate activity counts measured by some devices, although this may be reduced by filtering the accelerometer signal (64). The number of assessment days and hours of use per day are also important factors that may influence the reliability of the physical activity assessment (65;66). Interestingly, compared to the other days of the week especially Sundays seem to be days of less physical activity in GOLD stage I to III patients (65)A recent study demonstrates that for cross-sectional analyses two to three days are sufficient for reliable measurement of physical activity in patients GOLD stage IV, whereas up to 5 days of measurement are required in patients with GOLD stage I (65). For measurements that aim to assess longitudinal changes 4 days were shown to be sufficient to demonstrate treatment effects following pulmonary rehabilitation in moderate to severe COPD, when weekends were excluded from the analysis (67).

The use of accelerometers certainly presents limitations. It should be noted that there is little uniformity in output from the various types of accelerometers, what makes it difficult to compare studies using different devices (68). Another limitation is that estimates of energy expenditure for individual patients may be inaccurate, especially among those with functional limitations due to chronic diseases that affect walking speed and efficiency of movement (69). Furthermore, purchase costs vary considerably between devices.

### *6.4 Doubly labeled water*

The doubly labeled water (DLW) method provides an indirect assessment of total energy expenditure by the body over a substantial period of time (e.g. 2 weeks). The technique is described elsewhere (70). Briefly, known doses of deuterium ($^2H_2O$) and $^{18}O$ are ingested ($^2H_2O$ & $H_2{}^{18}O$). The deuterium washes out of the body through the urine, whereas the $^{18}O$ is eliminated as urine water and $CO_2$. The difference between the wash out of the two (typically measured in urine samples) provides an estimate of CO2 production by the body, which can be converted to energy expenditure (71).

The biggest drawback of the technique in the context of physical activity assessment in COPD is that it does not allow separating energy expenditure linked to physical activity and energy expenditure linked to basal metabolic rate or diet induced metabolism. Thus although the DLW technique is used to estimate total energy expenditure in patients with COPD(63;72;73) its ability to estimate physical activity is compromised by a number of assumptions that may be correct for healthy subjects but not for patients with COPD. For example one study used DLW in severe COPD and concluded that active energy expenditure was even higher in COPD compared to controls, which might be related to the increased oxygen cost of breathing and decreased mechanical efficiency in patients with COPD(72). On the other hand, actual physical activity levels are lower in patients with COPD (65). The DLW technique should likely be restricted to questions on caloric balance in patients with COPD rather than questions concerning the amount and intensity of physical activity. It can be questioned whether the technique should remain the ‘gold standard’ to validate monitors that measure the amount and intensity of movement in COPD, even though DLW will very likely remain a ‘gold standard’ for measuring the caloric cost of physical activity.

**7. Levels of physical activity in patients with COPD**

Patients with COPD have significantly lower levels of physical activity as compared to healthy controls (65;74-81). Existing data shows that time spent walking is significantly lower in COPD patients compared to healthy, age-matched persons (74;76;77;80;82). These findings appear to be consistent across settings, cultural background, geographic area and methods used to measure physical activity. In addition, movement intensity of patients with

COPD is lower compared to age-matched healthy subjects, which indicates that patients with COPD walk at a slower pace (74). Current data suggest that patients with COPD reduce their physical activity early in the course of the disease (83-85). Accordingly, most patients do not meet currently recommended physical activity levels. For example in one study only 26% of 177 patients with a mean FEV1 52% predicted achieved at least 30 consecutive minutes of moderate intensity activity on at least 5 days; this increased to 50 % if the 30 minutes were accomplished in bouts of at least 10 minutes each (86). Corroborating these results, another study reported that only 29% of 73 patients with COPD achieved a mean of at least 30 minutes of moderate physical activity summed up throughout the day (87). Compared to controls COPD patients had a reduction by 50 % of their minutes of moderate physical activity per day, which was even more reduced when bouts of at least 10 min were compared between controls and COPD patients (88).

## 8. Factors associated with physical activity in COPD

This section addresses associations between physical activity and clinical characteristics of patients with COPD, such as disease severity, comorbidities, exacerbations, and behavioral factors. Since most of the studies are cross-sectional it is not possible to draw conclusions regarding the directionality of the established associations (89). It should be acknowledged that in general, physical activity is dependent of many factors, which include biological, behavioral, genetic, social, environmental, cultural and policy factors (90). In this section we will discuss those aspects that are specifically studied in COPD.

### *8.1 Lung function*

FEV1 shows a weak to moderate positive association with objectively measured physical activity in patients with COPD (39;65;74;77;79;80;91;92); Table 2). In general, $FEV_1$ explains only a small proportion of the variation in physical activity in subjects with COPD. Directly measured maximal voluntary ventilation may provide an increased correlation with physical activity in this population (92). Fewer studies have investigated the relationship between physical activity and other lung function measures. While three studies found weak-to-moderate positive associations between physical activity and diffusion capacity (74;80;93), one study showed a strong and independent linear association (94). A robust inverse association was found between dynamic hyperinflation (measured in the laboratory during cardiopulmonary exercise test on a stationary cycle ergometer) and physical activity (95). Overall, while increasing severity of lung function impairment is associated with reduced physical activity in subjects with COPD, the relationship is relatively weak. Therefore, levels of physical activity cannot be accurately predicted from resting lung function parameters.

### *8.2 Exercise performance*

Physical fitness, which can be measured by various exercise tests, comprises a set of attributes that relates to the ability to perform physical activity (4). Accordingly, most studies in COPD have found moderately positive associations between either 6-minute walk distance or peak work rate in an incremental exercise test and objectively measured physical activity (40;65;74;79;96) (Table 3).

Two studies evaluated the predictive power of the 6-minute walk distance to identify physically inactive COPD patients with an objectively measured physical activity level lower than 1.4 (i.e. less that 40% of total daily energy expenditure is related to physical activity). In both studies 6-minute walk distance - even though moderately associated with physical activity - was found to be of limited value to reliably identify physically inactive COPD patients (40;65).

*8.3 Self-efficacy*

Self-efficacy, an individual's belief in his or her capability of performing a specific task in a specific situation, is influenced by expectations of ability to perform the task and its outcome (97). Theoretically, higher levels of self-efficacy may be associated with increased physical activity; and higher levels of physical activity may result in enhanced self-efficacy belief. However, self-efficacy for walking, assessed in COPD using the Self-Efficacy Questionnaire – Walking (SEQ-W) instrument, was only weakly associated with objectively measured physical activity (91). Furthermore, in another study of 165 patients with COPD, general self-efficacy as measured with the General Self-Efficacy Scale (SES6) was not associated with physical activity (98).

*8.4 Socio-demographic factors and environment*

Several socio-demographic and environmental factors including ethnicity, socioeconomic status, job availability, education level, patient choices about where to live, and seasonal variations in temperature and humidity have the potential to influence performance of daily physical activity among persons with COPD.

Among healthy adults, lower physical activity levels have been associated with lower socioeconomic status, lower education level and non-Caucasian race (99-101). However, this may not be the case for patients with COPD, since two studies have demonstrated a relationship between lower physical activity levels and higher socioeconomic status (102;103). In these studies, it is difficult to distinguish the impact of socioeconomic status from that of other influences, such as geographic location and ethnic and cultural differences, but it is possible that increased dependence on walking and public transportation among persons of lower socioeconomic status accounts for the findings. Also, both studies focused on persons with severe airflow limitation; hence the findings may not be applicable to patients with less severe lung function impairment.

Weather, climate and altitude conditions can also influence physical activity levels among persons with COPD. Extremes of heat or cold and or high environmental levels of particulates or other air pollutants can trigger increased symptoms, bronchoconstriction and acute exacerbations (104-106) and may pose a barrier to exercise and activity adherence (107;108). Accordingly, seasonal variations in daily physical activity have been reported (93;109-111), with a tendency for lower activity during periods with lower temperature. High altitude environments may also influence physical activity levels, since elevation in altitude leads to worsening resting and/or exercise hypoxemia and reduced exercise tolerance among patients with COPD (112). Geographical location *per se* may not strongly influence activity levels (e.g., independently of other factors such as climate, altitude or socioeconomic status) as no significant differences in physical activity were observed among patients with varying severity of COPD across diverse geographic locations in Europe and the United States (78;79). Finally, physical activity levels may be influenced by the day of the week; total activity and activity intensity were lower on Sundays or weekend as compared to other days (63;65).

### *8.5 Exacerbations of COPD*

Physical activity is dramatically reduced during and after hospitalization due to an exacerbation of COPD (113;114). Furthermore, recovery time is prolonged over several weeks and physical activity may not return to pre-exacerbation activity levels (113;114). Even patients with milder exacerbations, which do not require hospitalization, tend to stay indoors during the exacerbation period (115). Moreover, patients with a history of frequent exacerbations reduce their time spent outdoors at a faster rate compared with those with infrequent exacerbations, and thus are more likely to become housebound (115). This is confirmed by another study demonstrating that a history of more than one exacerbations is correlated with lower physical activity levels (79).

### *8.6 Comorbidities*

Comorbidities are common in COPD (116-118) and may independently impact physical activity levels. A cross-sectional study of 170 patients with COPD  demonstrated that left ventricular cardiac dysfunction (assessed by elevated NT-pro-BNP and echocardiographic assessment of diastolic function) was associated with reduced physical activity levels, independent of COPD severity assessed by GOLD stage or the multidimensional BODE score (119). In this study, depression, anemia, systemic arterial blood pressure, and nutritional depletion were not associated with reduced physical activity levels (119). In the same cohort physical activity levels were significantly lower among patients with metabolic syndrome and COPD across all GOLD stages as compared with the patients without metabolic syndrome (120). It is not yet clear, which of the components of the metabolic syndrome contributed to this finding. For instance, obese COPD patients have lower activity levels compared to underweight- and normal weight patients (121;122). Furthermore, diabetes is strongly associated with inactivity in COPD, independent of other confounders (102). In a cohort of newly diagnosed COPD patients, physical inactivity was more strongly associated with the presence of comorbidities compared with airflow obstruction (123).

Quadriceps muscle strength and mass, which are commonly reduced in patients with COPD, are positively correlated with physical activity in several studies (74;79;85). In one study quadriceps muscle strength was predictive of physical activity, independent of $FEV_1$ (79). In contrast, handgrip strength did not correlate with physical activity in patients with COPD (94;119).

Mood disturbances such as symptoms of anxiety and depression are highly prevalent in patient with COPD (124). Of the six studies examining the relationship of physical activity and depression in patients with COPD (79;80;119;125-127) only two found significant associations (80;127). In one study higher levels of anxiety were associated with higher levels of physical activity whereas more depressive symptoms were associated with lower physical activity only when anxiety was part of the statistical model (127).

8.7 Systemic inflammation

In the general population a growing body of evidence demonstrates that physical activity, inflammation and immunity are tightly linked, with regular moderate physical activity reducing systemic inflammation (128-131). Potential mechanisms underlying these observations include the release of anti-inflammatory myokines by contracting skeletal muscles (132). In COPD, four studies demonstrated that higher levels of low-grade systemic inflammation are associated with lower levels of physical activity even after adjusting for relevant confounders (79;94;119;133). Whether anti-inflammatory mechanisms of regular physical activity or COPD-specific mechanisms of systemic inflammation underlie the associations of systemic inflammation and physical activity in COPD needs to be elucidated in further longitudinal studies (134).

*8.8 Health status*

Various assessments of health status have been related to physical activity measurements in patients with COPD. Most studies showed that an impaired health status assessed either by generic or disease-specific instruments is weakly to moderately related to a lower amount and intensity of physical activity (79;91;102;135;136). Changes in physical activity over time parallel trends in health status (137). Since most health status questionnaires have items addressing physical activity this could obviously affect these relationships.

*8.9 Symptoms*

Breathlessness on exertion is the primary symptom limiting exercise, which in turn leads to reduced physical activity in patients with COPD (138). Accordingly, patients' perception of breathlessness on exertion is reported to be a barrier for participation in exercise and daily activities of daily living (110;139). Indeed, greater levels of dyspnoea as measured by the modified Medical Research Council Dyspnoea Scale are related to lower levels of physical activity in patients with COPD (65;79).

Also fatigue is reported to be a frequent symptom in patients with COPD (140). There is one study that evaluated the association of fatigue assessed by the Functional Assessment of Chronic Illness Therapy - Fatigue questionnaire and physical activity. After adjusting for several confounders physical activity was demonstrated to be associated with fatigue in patients with COPD.  (79). Whether and to what extent pain symptoms may affect physical activity in patients with COPD remains currently unknown.

**9. Effect of physical inactivity on hospitalizations in patients with COPD**

To date seven prospective longitudinal studies have assessed the association between levels of regular physical activity and hospital admission or readmission due to COPD exacerbations (30;113;141-145). All studies consistently showed a statistically significant association of low physical activity levels with increased risk of hospitalizations. Although all studies reported associations adjusted for confounders, just one study adjusted for previous COPD hospitalizations, which is one of the most important risk factor for readmission (146). Importantly, the studies have shown that the amount of regular physical activity needed to obtain a significant effect on admissions due to COPD is relatively small, equivalent to walking or cycling 2 hours per week (30;113;141-145).

## 10. Effects of physical inactivity on survival in COPD

Three longitudinal studies with a follow-up of 3 to 12 years have demonstrated that low levels of physical activity predict all-cause mortality in patients with COPD after controlling for relevant confounding factors (144;145;147). The relationship was consistent across differing settings, patient characteristics, and methods used to measure physical activity. In one study that separated respiratory-related from cardiovascular and all-cause mortality, the greatest effect was on the former (144). Recently, an assessment of physical activity has also been included as a prognostic factor in a multidimensional prognostic score for stable COPD patients (148).

Whether and to what extent improvements in physical activity levels may lower the risk of dying remains unknown in patients with COPD. Furthermore, it seems reasonable to hypothesize that patients who have a decline in physical activity over time have a worse prognosis compared to those patients who remain physically active.

## 11. Treatment strategies to improve physical activity

### *11.1 Pharmacologic therapy*

While it is well-known that bronchodilators improve dyspnoea and exercise tolerance, only few studies have investigated the impact of bronchodilator therapy on physical activity (149-151). Two studies had positive results with regard to improvements of physical activity following bronchodilator treatment. Of these, one study (23 patients) was a non-randomized open-label study of a long-acting beta-agonist in a small number of patients (150), while the other study was a retrospective subgroup analysis (151). By contrast, two randomized, placebo-controlled, multicenter study could not demonstrate a change in physical activity following therapy with a long-acting bronchodilator (149;152). Therefore, it remains currently unknown, whether bronchodilator therapies that are known to improve exercise capacity will also either improve physical activity or prevent deterioration of physical activity over time in patients with COPD.

*11.2 Ambulatory oxygen therapy*

Oxygen therapy improves exercise tolerance in hypoxemic COPD patients, but whether activity levels are also enhanced is unclear. A small, randomized trial of replacing heavier oxygen tanks with lightweight ambulatory oxygen therapy failed to detect improvements in activity monitor assessments of physical activity over a 6 month period (153).

*11.3 Pulmonary rehabilitation*

Pulmonary rehabilitation is a "comprehensive intervention to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors" (154). Pulmonary rehabilitation has been demonstrated clearly to reduce dyspnea, increase exercise capacity and improve quality of life in patients with COPD. Increases in exercise capacity in combination with behavioral change may also have the potential to increase physical activity in patients with COPD. Despite this rationale the 10 studies that evaluated the effect of pulmonary rehabilitation on physical activity (80;82;155-162) have yielded inconsistent results; four showed an increase of physical activity (80;160-162) and six failed to do so (82;155-159). In the negative studies, the lack of improvement in physical activity was observed despite a concomitant increase in exercise capacity and quality of life. A systematic review and meta-analysis of single-group and randomized trials of the effect of exercise training (not necessarily pulmonary rehabilitation) on physical activity concluded that this intervention conferred a significant but small increase in this outcome (163).

*11.4 Behavior changes, feedback, counseling*

Solely increasing the exercise capacity of patients with COPD may be insufficient to increase participation in self-directed leisure time activity (47;80;82;155;157-162;164). Widespread acknowledgment of the exercise maintenance problem has led to the identification of behavioral factors related to participation in daily physical activity and to the development of interventions targeting these factors.

Interventions including self-monitoring of activity behavior using activity monitors in combination with behavioral counseling in patients with COPD might have the potential to change physical activity behavior (45-47;165-167). However, the evidence base is weak since only few studies have been conducted using small samples (46;47) often without a control group (45;165;166). Larger studies with long term follow up are needed in patients with COPD.

Key components that increase the effectiveness of behavioral interventions have already been summarized in several meta-analyses and international guidelines (168-172) and include mobilizing social support, using well-described/established behavior change and self-regulatory techniques (self-monitoring, stimulus control, problem solving, relapse prevention management, goal setting, self-reinforcement, providing feedback on performance and developing action plans), providing higher contact time or contact frequency, and assessing the readiness / motivation to change (168;170). Motivational interviewing techniques have further been recommended as a collaborative communication approach (168).

### 11.5 Summary of treatment strategies to improve physical activity

To date, only a few randomized controlled trials have studied the efficacy of pharmacologic or non-pharmacologic treatment strategies on daily physical activity in patients with COPD. Therefore, there is an urgent need for additional well-designed trials. Based on the correlates of physical activity, it seems reasonable to focus in future studies on physical, non-physical and environmental factors to improve physical activity in patients with COPD. Moreover, future trials should not only focus on improvements of physical activity but also on the prevention of loss of physical activity.

**12. Moving forward**

The scientific foundation regarding the clinical importance of assessing and improving physical activity in patients with COPD has grown considerably in the last decade. Nevertheless, many questions remain unanswered and the methodology of physical activity assessment needs to be further standardized. Therefore, this Task Force identifies the following major areas that need to be further addressed in the coming years:

1. In addition to smoking cessation the disease-modifying potential of increased physical activity in smokers without COPD and in patients with all degrees of airflow limitation should be explored.
2. Further understanding is needed regarding the concepts to optimize the impact of the pharmacological and non-pharmacological interventions that aim to maintain or increase physical activity levels in patients with COPD.
3. Research should be undertaken to understand how improvements in exercise capacity, dyspnea, and self-efficacy following intervention (e.g. pulmonary rehabilitation, pharmacological therapy) might translate into increased physical activity.
4. The methodology to measure physical activity needs to be further standardized and formal guidance on that should be provided in future. Such methodologies could rely on objective and accurate assessment of physical activity, patient reported assessment of physical activity experience or combination thereof.

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Table 1. Studies on physical inactivity and lung function decline or COPD incidence.

| Study | Design and setting | Number of subjects and follow-up | Subjects' characteristics | Physical activity assessment | Outcome(s) | Main Results |
|---|---|---|---|---|---|---|
| Jakes et al. [ref 26] | Population-based cohort<br><br>UK | n=12,283 mean 3.7 years follow-up | 45% men<br><br>mean age: 59 (9) y<br><br>mean $FEV_1$: 3.0 (0.7) L in men, and 2.2 (0.5) L in women | Standardised questionnaire | $FEV_1$ decline (mL/y) | Climbing more stairs is associated with slower $FEV_1$ decline in women (-0.31, -0.11, -0.03, and 0.04% change in FEV1 in none, 1-5, 6-10 and >10 flights per day, p-for-trend<0.004).<br><br>Participation in vigorous leisure time activities is associated with slower $FEV_1$ decline in women (-0.22, -0.34, 0.27, and 0.03% change in $FEV_1$ in none, <0.25, 0.25-1, and >1 h per week, p-for-trend<0.004).<br><br>Based on a linear regression model adjusted for age, smoking status, and percent change in weight.<br><br>No association found in men. |
| Pelkonen et al. [ref 27] | Cohort of rural men with a high physical activity level | n=186<br><br>25 years follow-up | 100% men<br><br>mean age: 54 (5) y<br><br>mean $FEV_{0.75}$: 2.9 (0.6) L | Validated questionnaire | $FEV_{0.75}$ decline (mL/y) | Decline in $FEV_{0.75}$ over 25 years was -44.4, -40.5, and -36.5 mL/y, p-for-trend=0.035 for low, middle, and high physical activity.<br><br>Based on a linear regression model adjusted for age, height and |

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| | Finland | | | | | smoking habits. |
| Cheng et al. [ref 28] | Convenience sample from a clinic<br><br>USA | n=5707<br><br>mean 1.6 years follow-up | 87% men<br><br>age range 25-55 years | Self-report | $FEV_1$ and FVC decline (mL/y) | Men who during the follow-up remained in the active category increased 50ml of $FEV_1$ and 70mL of FVC while subjects who remained in the sedentary group reduced 30 and 20 mL of $FEV_1$ and FVC, respectively.<br><br>Based on generalised least squared regressions adjusted for smoking and drinking habit change, age, baseline height, baseline lung function levels, and follow up time.<br><br>No association found in women. |

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| Garcia-Aymerich et al. [ref 29] | Population-based cohort<br><br>Denmark | n=6790<br><br>10 years follow-up | 43% men<br><br>mean age: 52 (12) y<br><br>mean $FEV_1$: 2.7 (0.9) L<br><br>mean FVC: 3.3 (1.0) L | Validated questionnaire | COPD incidence ($FEV_1$/FVC≤70 %) | Active smokers with moderate to high physical activity show a reduced risk of developing COPD as compared to the low physical activity group (OR=0.77, p=0.027).<br><br>Based on logistic regression models adjusted for gender, age, education, body mass index, weight change during follow-up, asthma, dyspnea, sputum, smoking status, and smoking duration.<br><br>No association found in former or never smokers. |

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| | | | | | $FEV_1$ and FVC decline (mL/y) | Active smokers with moderate and high physical activity show a reduced $FEV_1$ decline compared to those with low physical activity (relative change of +2.6 and +4.8 mL/y of $FEV_1$, p-for-trend=0.006)<br><br>Active smokers with moderate and high physical activity show a reduced FVC decline compared to those with low physical activity (relative change of +2.6 and +7.7 mL/y of FVC, p-for-trend<0.0001)<br><br>Based on linear regression models adjusted for gender, age, education, body mass index, weight change during follow-up, ischemic heart disease, dyspnea, sputum, smoking status, smoking duration, alcohol consumption, and baseline lung function levels.<br><br>No association found in former or never smokers. |

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| Garcia-Aymerich et al. [ref 30] | Population-based cohort<br><br>Denmark | n=6568<br><br>mean 16 years follow-up | 41% men<br><br>mean age: 49 (11) y<br><br>mean $FEV_1$: 2.7 (0.8) L<br><br>mean FVC: 3.4 (1.0) L | Validated questionnaire | COPD incidence ($FEV_1/FVC \leq 70$ %) | Subjects with moderate to high physical activity show a reduced risk of developing COPD as compared to the low physical activity group (OR=0.79, p=0.025).<br><br>Based on a logistic regression model adjusted for gender, age, education, body mass index, sputum, asthma and smoking, and weighted using marginal structural models to allow repeated measures of physical activity, lung function, and covariates. |
| | | | | | $FEV_1$ and FVC decline (mL/y) | Subjects with moderate and high physical activity show a reduced $FEV_1$ decline compared to those with low physical activity (relative change of +7.4 and +10.3 mL/y of $FEV_1$, p-for-trend<0.001)<br><br>Subjects with moderate and high physical activity show a reduced FVC decline compared to those with low physical activity (relative change of +6.9 and +10.0 mL/y of FVC, p-for-trend<0.001)<br><br>Based on linear regression models adjusted for gender, age, education, body mass index, sputum, smoking, alcohol and baseline lung function levels, and weighted using marginal structural models to allow repeated measures of physical activity, lung function, and covariates. |

Table 2. Relationship between $FEV_1$ and physical activity in some representative cross-sectional studies.

| Study | Design and setting | Number of subjects (male/female) | Physical activity assessment | Main objective | R value | P value | Main results |
|---|---|---|---|---|---|---|---|
| Steele et al. [ref 39] | Single-center convenience sample US | 47 (44/3) | Accelerometer | Feasibility of accelerometer measurement | 0.62 | P<0.001 | Preliminary data suggesting that a triaxial movement sensor is a reliable, valid, and stable measure of walking and daily physical activity in COPD patients. |
| Belza et al. [ref 91 ] | Single-center convenience sample US | 63(60/3) | Accelerometer | Evaluation of correlates of physical activity | 0.37 | P<0.01 | Physical activity is most significantly related to walking abilities |
| Pitta et al. | Single-center | 50 (36/14) | Accelerometer | Comparison of physical | 0.28 | p<0.05 | Patients with COPD are markedly inactive in daily life. Functional exercise capacity is the strongest correlate |

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| [ref 74] | convenience sample Belgium | | | activity in COPD with healthy subjects | | | of physical activity. |
| Walker et al. [ref 80] | Single-center convenience sample UK | 23 (12/11) | Accelerometer | Evaluation of lower limb activity and the association of laboratory assessments with physical activity before and after rehabilitation in COPD | 0.57 | P<0.001 | Physical activity in patients with COPD is closely related to leg activity, which is reduced compared with controls of similar age. |
| Hernandes [ref 77] | Single-center convenience | 40 (18/22) | Accelerometer | Evaluation of physical activity and its | 0.17 | P=ns | Physical activity correlates only moderately with maximal and functional exercise capacity. |

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| | sample<br>Brazil | | | clinical correlates in COPD in Brazil | | | |
| Watz et al.<br>[ref 65] | Single-center<br>convenience sample<br>Germany | 163 (122/41) | Accelerometer | Various analyses of physical activity and its clinical correlates in COPD | 0.42 | P<0.01 | Clinical characteristics of patients with COPD only incompletely reflect their physical activity |
| Waschki et al.<br>[ref 79] | Multi-center<br>convenience sample<br>UK, Netherlands | 127(79/48) | Accelerometer | Evaluation of compliance with wearing an accelerometer and the relationship of disease | 0.65* | P<0.001 | Excellent compliance with wearing a physical activity monitor in a multicenter study.<br>Consistent associations of physical activity with relevant disease characteristics in a multicenter study. |

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| | | | | characteristics with physical activity in a multi-center study | | | |

* Standardized regression coefficient beta adjusted for age, sex, study site, and BMI > 30

Table 3. Relationship between exercise tolerance and physical activity in some representative cross sectional studies.

| Study | Design and setting | Number of subjects (male/ female) | Main objective | Physical activity assessment | Exercise tolerance assessment | R value | P value | Main results |
|---|---|---|---|---|---|---|---|---|
| Steele et al. [ref 39] | Single-center convenience sample US | 47 (44/3) | Feasibility of accelerometer measurement | Accelerometer | 6MWD | 0.74 | P<0.001 | Preliminary data suggesting that a triaxial movement sensor is a reliable, valid, and stable measure of walking and daily physical activity in COPD patients. |

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| Belza et al. [ref 91 ] | Single-center convenience sample US | 63(60/3) | Evaluation of correlates of physical activity | Accelerometer | 6MWD | 0.60 | P< 0.001 | Physical activity is most significantly related to walking abilities |
| Pitta et al. [ref 74] | Single-center convenience sample Belgium | 50 (36/14) | Comparison of physical activity in COPD with healthy subjects | Acclerometer | 6MWD, % pred.<br>Wmax, % pred.<br>Peak VO2, % pred. | 0.76<br>0.64<br>0.33 | P<0.0001<br>P<0.0001 | Patients with COPD are markedly inactive in daily life. Functional exercise capacity is the strongest correlate of physical activity. |
| Eliason et al. [ref 96] | Multi-center convenience sample Sweden | 44 (28/16) | Associations between physical activity and clinical characteristics of COPD | Accelerometer | 6MWD | 0.34* | P=0.03 | Mean physical activity level and physical activity of at least moderate intensity are positively associated |

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| | | | | | | | | with exercise capacity |
| Waschki et al. [ref 79] | Multi-center convenience sample UK, Netherlands | 127 (79/48) | Evaluation of compliance with wearing an accelerometer and the relationship of disease characteristics with physical activity in a multi-center study | Accelerometer | 6MWD | 0.47** | P<0.001 | Excellent compliance with wearing a physical activity monitor in a multicenter study. Consistent associations of physical activity with relevant disease characteristics in a multicenter study. |
| Watz et al. [ref 65] | Single-center convenience sample Germany | 163 (122/41) | Various analyses of physical activity and its clinical correlates in COPD | Accelerometer | 6MWD | 0.46 | P<0.001 | Relation to clinical outcomes |

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| Van Gestel et al. [ref 40] | Single-center convenience sample Switzerland | 70 (49/21) | Predicting physical activity levels from 6MWD | Accelerometer | 6MWD | 0.69 | P<0.001 | 6MWD cannot reliably predict physical inactivity |

6MWD, 6-minute walk distance; Wmax, maximal workload; peak VO2, peak oxygen uptake; * standardized regression coefficient beta; ** standardized regression coefficient beta adjusted for age, sex, study site, and BMI > 30